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INCIPIENT CAVITATION IN AXIAL FLOW PUMPS

Part II

Hydrodynamic Noise and Tip Vortex Cavitation

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ABSTRACT

The first occurrence of noise in an axial flow pump is correlated with the visually observed inception of cavitation for a range of tip clearances and flow rates. The magnitude of the sound level in the machine is determined as a function of the cavitation number for several tip clearances. However, the peak sound level does not depend much on tip clearances, and is about 35 db. above the ambient level.

INTRODUCTION

This report is a continuation of Part I* in which it was shown that tip clearance flows are responsible for incipient cavitation in unshrouded axial flow pumps. In this part attention is centered on noise measurements of incipient cavitation, and on the magnitude of the noise that occurs.

EXPERIMENTAL WORK

A. Determination of Incipient Cavitation in an Axial Flow Pump by Sound Measurements

Objectives: In Part I, measurements of the cavitation number for inception were made visually. However, it is possible that the minute bubbles characteristic of the first cavitation cannot be seen. This possibility and hence the reliability of the visual observations should be investigated by acoustic measurements.

Test Setup: The pump facility as described in Part I of this report was used for these experiments.

The case of the axial flow pump was outfitted with holes suitable for the installation of a hydrophone or sound pickup. These holes were located before, midway through and after the rotor blade row. A hydrophone, when

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*"Tip Clearance Flows and Incipient Cavitation", D. Rains, Hydrodynamics Laboratory, California Institute of Technology, Report E-56.1.

fitted into one of these 3/4-in. holes communicates with the flow through a 3/16-in. hole filled with vaseline. The vaseline provides a good acoustic path and prevents air from being trapped in the recess.

To avoid any difficulty of comparing the noise of one blade to another of different tip clearances, the tip clearance of all rotor blades was made the same. Figure 1 shows the sound pickup in place, together with auxiliary electronic equipment standing by. The signal from the pickup is amplified, filtered, and then observed on an oscilloscope. The oscilloscope sweep was synchronized with the rotation of the machine so that the complete rotor blade row can be studied in detail. The filters permit the sorting out of undesirable signals, and the making of spectrum measurements. For instance, machinery noise is generally concentrated in the range from 0 to 10 kilocycles, and thus it may easily be eliminated. Cavitation noise is primarily in a higher frequency range.

Procedure. The procedure for this set of experiments was similar to that for the visual observations except for the method of detection. For this work the sound pickup was located directly in front of the rotor blade row.

The incipient point was defined as the cavitation number at which noise peaks appeared on approximately 75% of the blades in the row. It is difficult to get a fine measure of "incipient" in a machine because of the sporadic nature of the cavitation due to small differences in the blades and the unsteady flow that each blade experiences.

Results. Figure 2 shows the incipient data taken by sound measurements on the same curve with the data from the visual observations.

B. Determination of the Noise Level in the Axial Flow Pump for Various Tip Clearances

Objectives. In order to compare the axial flow pump as a source of noise with other sources, noise level measurements should be made in a typical pump.

Test Setup. The test setup was the same as for the incipient runs except that an attenuator was added to the electrical circuit. A regular db-meter could not be used for it was desired to get the peak value of the noise from the moving sound sources, not just an average noise level.

Procedure. The attenuator was used for comparative measurements of sound intensity in the following way. The background noise was set by the oscilloscope gain to a given height on the screen cross hairs with the attenuator set at zero. Subsequently, during cavitation with the oscilloscope gain held constant, the noise peaks were matched to the reference cross lines with the attenuator. The attenuator is calibrated in decibels (db) so that the noise measurements are therefore read directly on it.

Results. The noise magnitude data is shown as a function of cavitation number on Fig. 3.

DISCUSSION AND CONCLUSIONS

In view of the intermittent nature of the cavitation in the machine and the resulting difficulty of comparing various methods of detection, the incipient cavitation data shown in Fig. 1 indicates good agreement between the acoustic and visual detection methods.

As shown by Fig. 3, noise was detected well before what has been called the incipient point. This noise was caused by the infrequent cavitation of only a few blades and so was not counted as being representative of the incipient point. Figure 3 also shows that the peak noise level is approximately independent of tip clearance, which is an interesting result inasmuch as the cavitation appearance varies a great deal in these cases. The maximum noise level observed was of the order of 35 - 40 db above the ambient level. These values are small compared to results on half bodies[1] but are comparable to measurements on a two-stage research pumpjet.[2] The slope of the noise level vs. cavitation number curve (Fig. 3) is small compared to values obtained in experiments on smooth bodies (see for example Fig. 4, Ref. 1). The reasons for this behavior are not as yet clear.

As the knowledge of tip clearance flow increases, ideas for the elimination of tip vortex cavitation on its modification to make it less of a sound source are being proposed. These schemes are being investigated in the hope that an improvement in axial flow pump performance will result.

REFERENCES

1. Kermeen, R. W. "Some Observations of Cavitation on Hemispherical Head Models", California Institute of Technology, Hydrodynamics Laboratory Report No. E-35.1.

2. Attias, J. J. "Evaluation of Noise Characteristics of a Two-Stage Axial Flow Pumpjet", NOTS 768, <u>Confidential</u>.

NOTATION

P_∞ = static pressure on the case of the pump directly before the rotor blades.

P_v = vapor pressure of the liquid at its measured temperature.

ρ = density of the pumped liquid.

W_∞ = mean velocity relative to the rotor blade tip.

φ = flow rate coefficient $= \dfrac{\text{axial velocity}}{\text{tip speed}}$

K = cavitation number $= \dfrac{P_\infty - P_v}{1/2\, \rho\, W_\infty^{\,2}}$

t = maximum thickness of the blade tip section.

δ_t = tip clearance.

λ = δ_t / t

α = angle of attack.

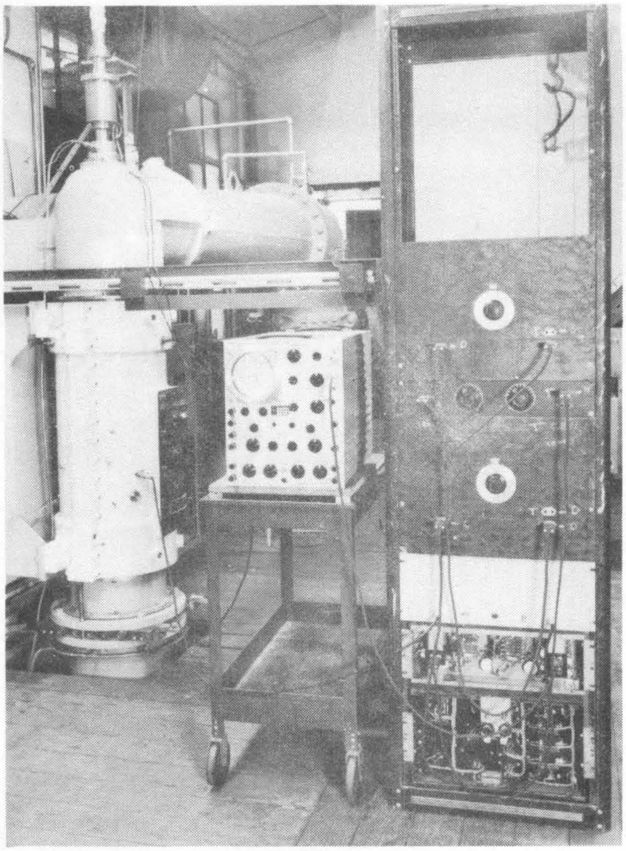

Fig. 1 - Sound measurement equipment.

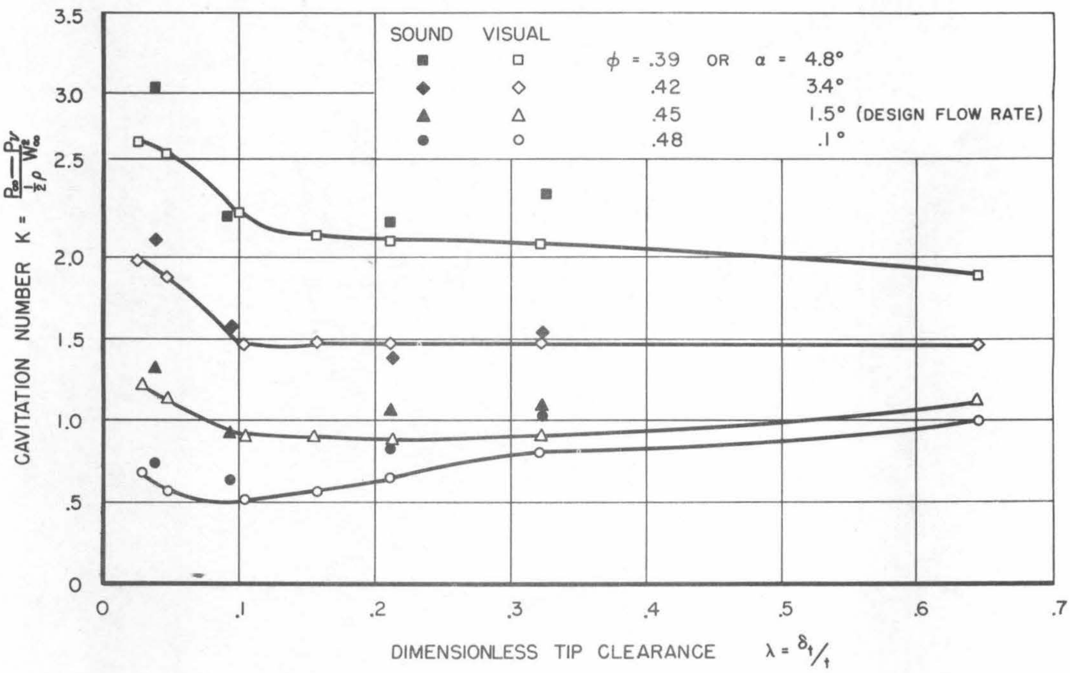

Fig. 2 - Incipient cavitation in an axial flow pump vs. tip clearance for various flow rates.

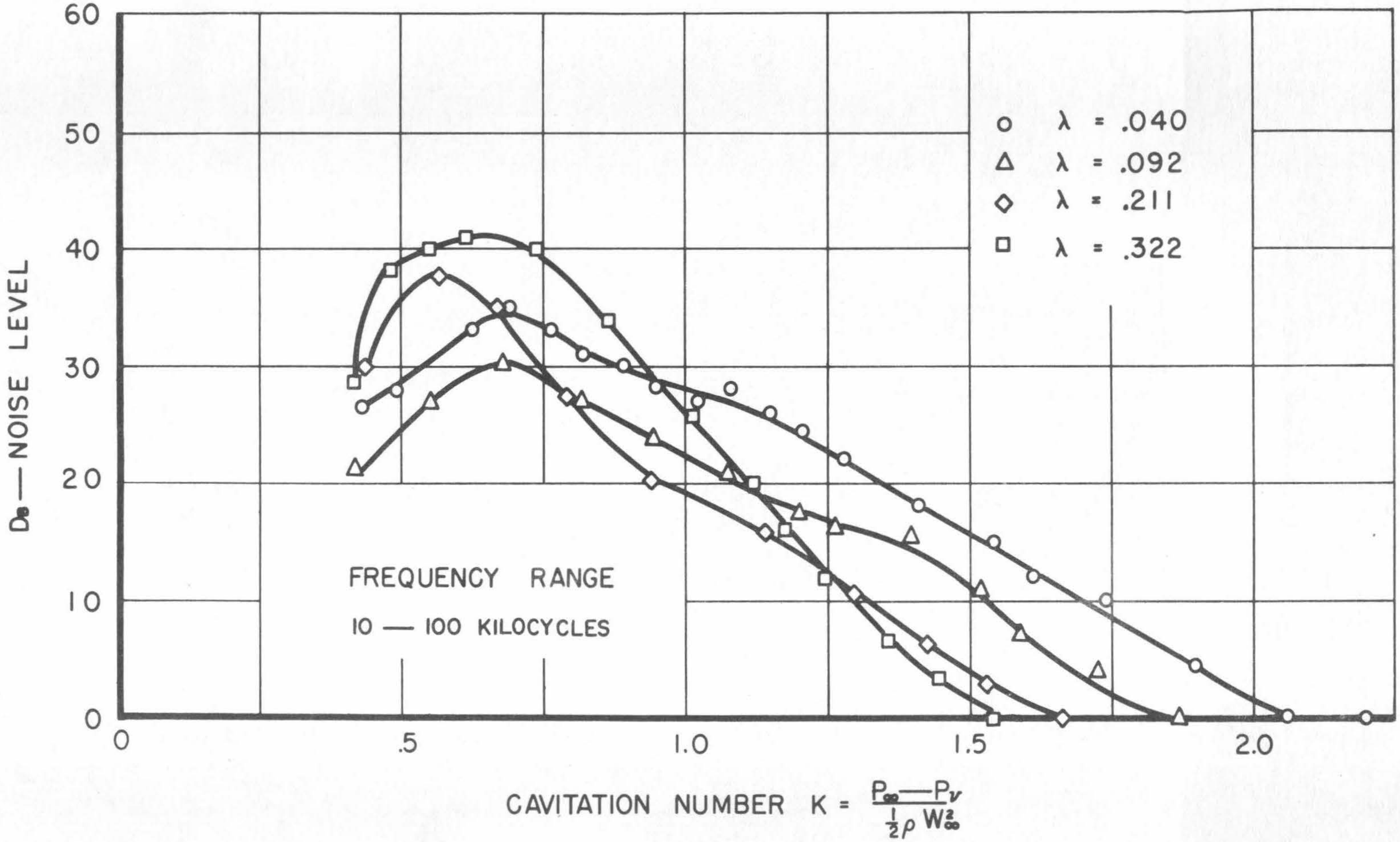

Fig. 3 - Noise level vs. cavitation numbers at design flow rate for various tip clearances.

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